Run 2b meeting: update on the Recycler Electron Cooling Project

Sergei Nagaitsev

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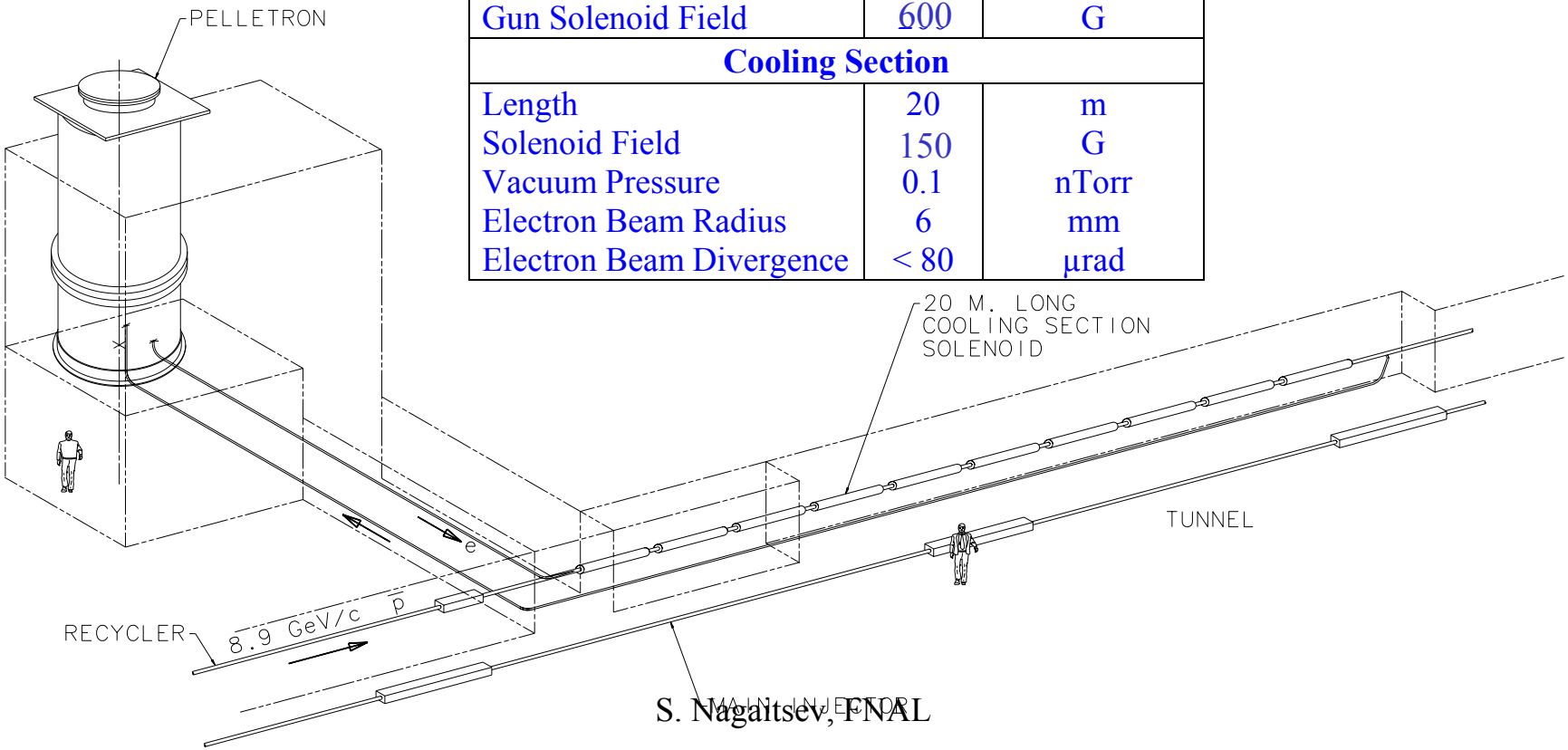
Schematic Layout of the Fermilab's Recycler Electron Cooling

Electron Cooling System Parameters

Parameter	Value	Units
Electrostatic Accelerator		
Terminal Voltage	4.3	MV
Electron Beam Current	0.5	A
Terminal Voltage Ripple	500	V (FWHM)
Cathode Radius	2.5	mm
Gun Solenoid Field	600	G
Cooling Section		
Length	20	m
Solenoid Field	150	G
Vacuum Pressure	0.1	nTorr
Electron Beam Radius	6	mm
Electron Beam Divergence	< 80	μrad



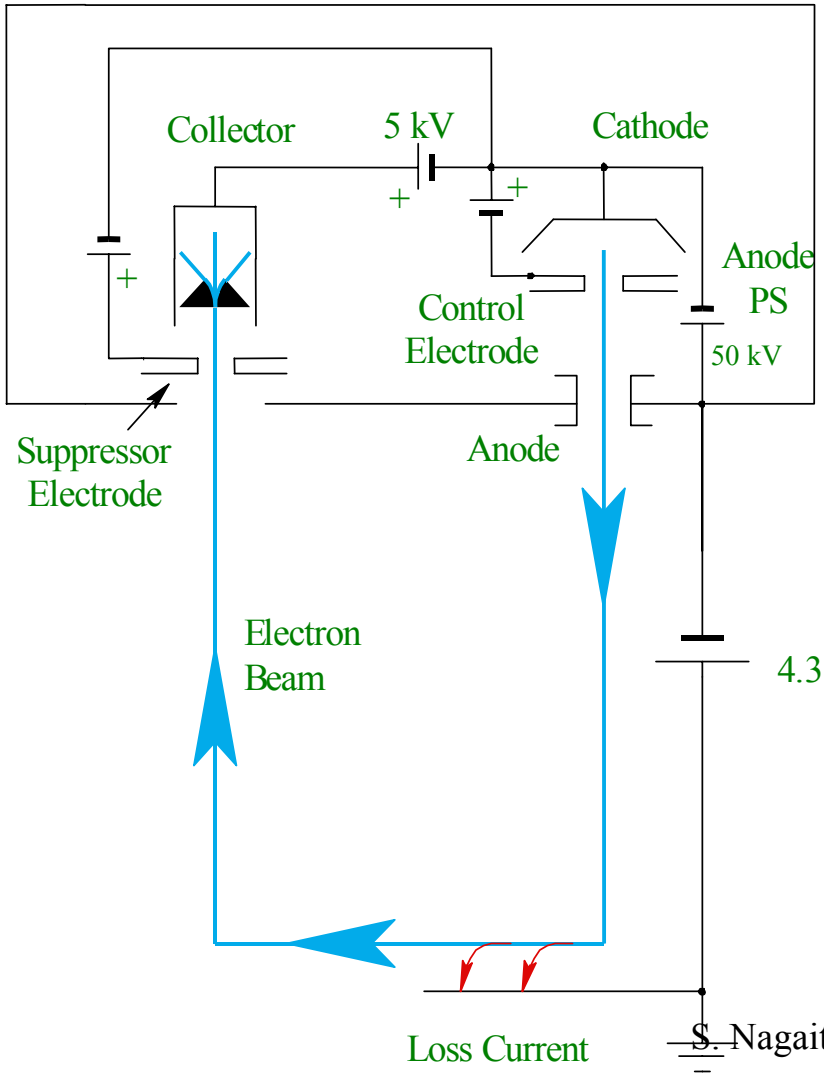
Electron Cooling R&D Project Goals

	Goal	Achieved?
• Electron beam current	0.5 A	YES
• Magnetic field at the cathode	600 G	YES
• Beam diam. at the cathode	5 mm	YES
• Electron beam kinetic energy	4.3 MeV	NO (3.5 MeV)
• Beam angular spread (cooling section)	80 μrad	N/A
• Energy spread (FWHM)	500 eV	YES
• Pressure (cooling section)	1×10^{-10} Torr	N/A
• Typical time between beam "crashes"	1 hour	NO (20 min) > 1 hour max.
• Crash recovery time	5 min	YES (2 min)
• Typical time between tank openings	1 month (initial) 6 months (final)	YES

Project issues to be covered in this talk

- Pelletron commissioning and beam recirculation tests
- Beam line elements
- Beam diagnostics
- Cooling section solenoid
- Civil construction plans

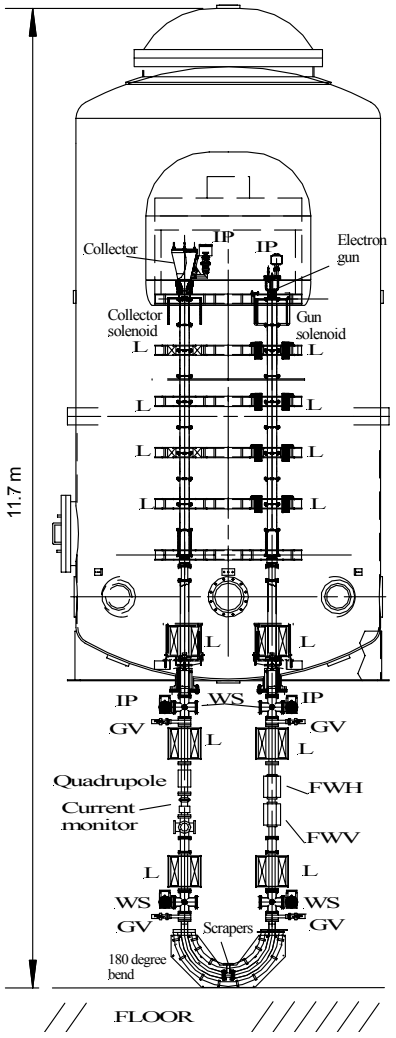
Simplified electrical schematic of the electron beam recirculation system.



For I= 0.5 A, ΔI= 5 μA:

- Beam power 2.15 MW
- Current loss power 21.5 W
- Power dissipated in collector 2.5 kW

Electron Cooling R&D Facility at WideBand (Recirculation experiment)



GOAL

- To demonstrate a 0.5 A recirculation for 1 hr. at 4.3 MV

HISTORY

Feb 99:	5 MV Pelletron ordered.
Jun 00:	Pressure tank installed at WideBand.
Dec 00:	Tank at 80 psig, 5 MV tests without vacuum tubes.
Feb 01:	Gun-side vacuum tubes installed and tested.
Mar 01:	Collector-side tubes installed. Operations began.
Apr 01:	Beam permit issued. All components in place.
May 01:	First beam of 30 μA in the collector at 4.3 MV.
July 01:	Reached 10 mA, HV conditioning is very unstable, tubes do not behave properly.
Aug 01:	Switched to operations with 3.5 MV. Routine conditioning to 4.3 MV.
Jan 02:	Reached stable 500 - 600 mA beam at 3.5 MeV

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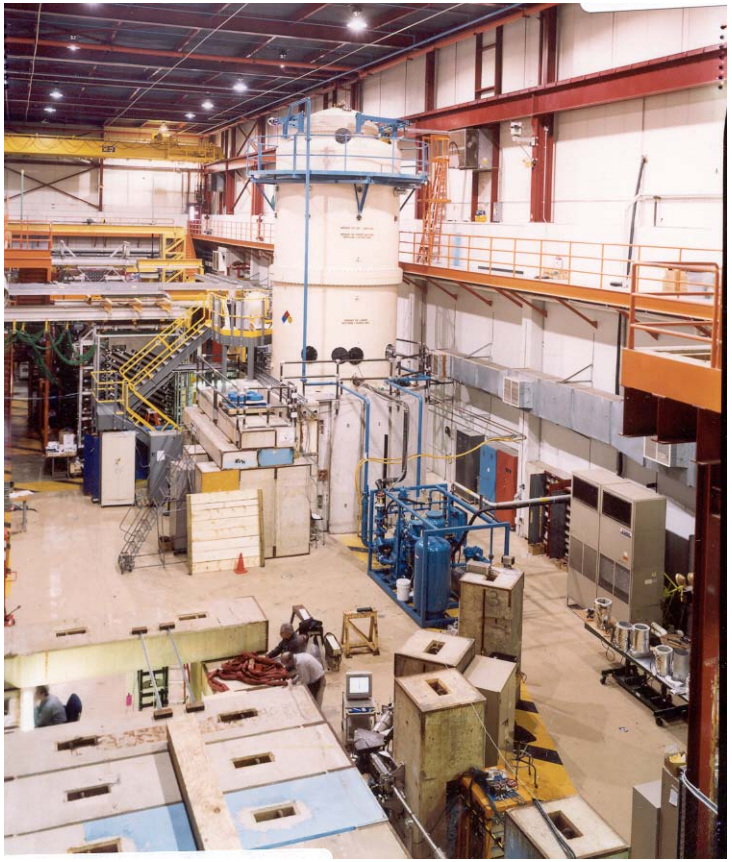
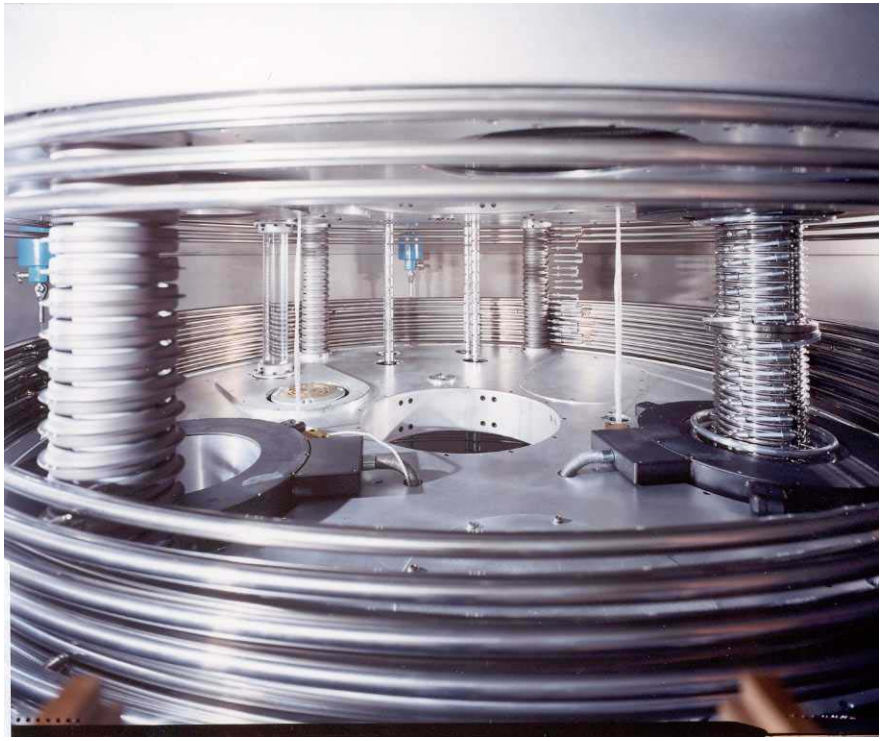
Fermilab Electron Cooling R&D Facility



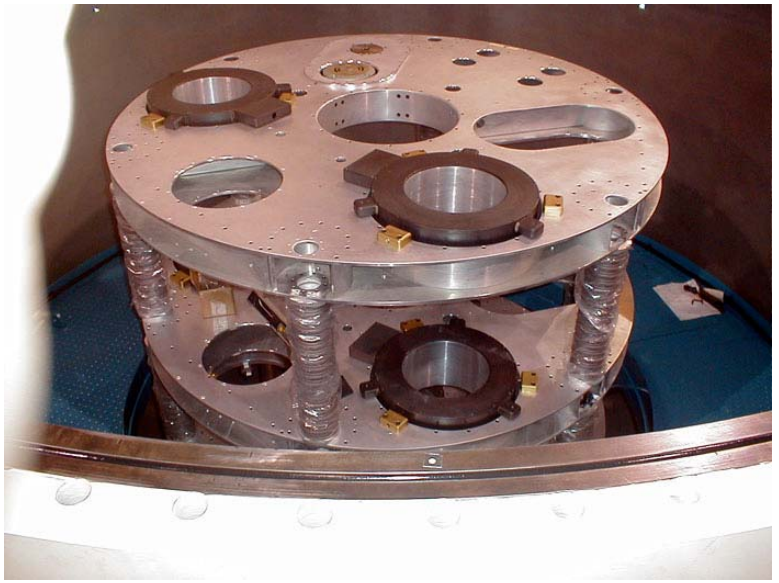
5 MV Pelletron installed



High-voltage column with grading hoops partially removed to show the accelerating tube (right) and the charging chains (far center).

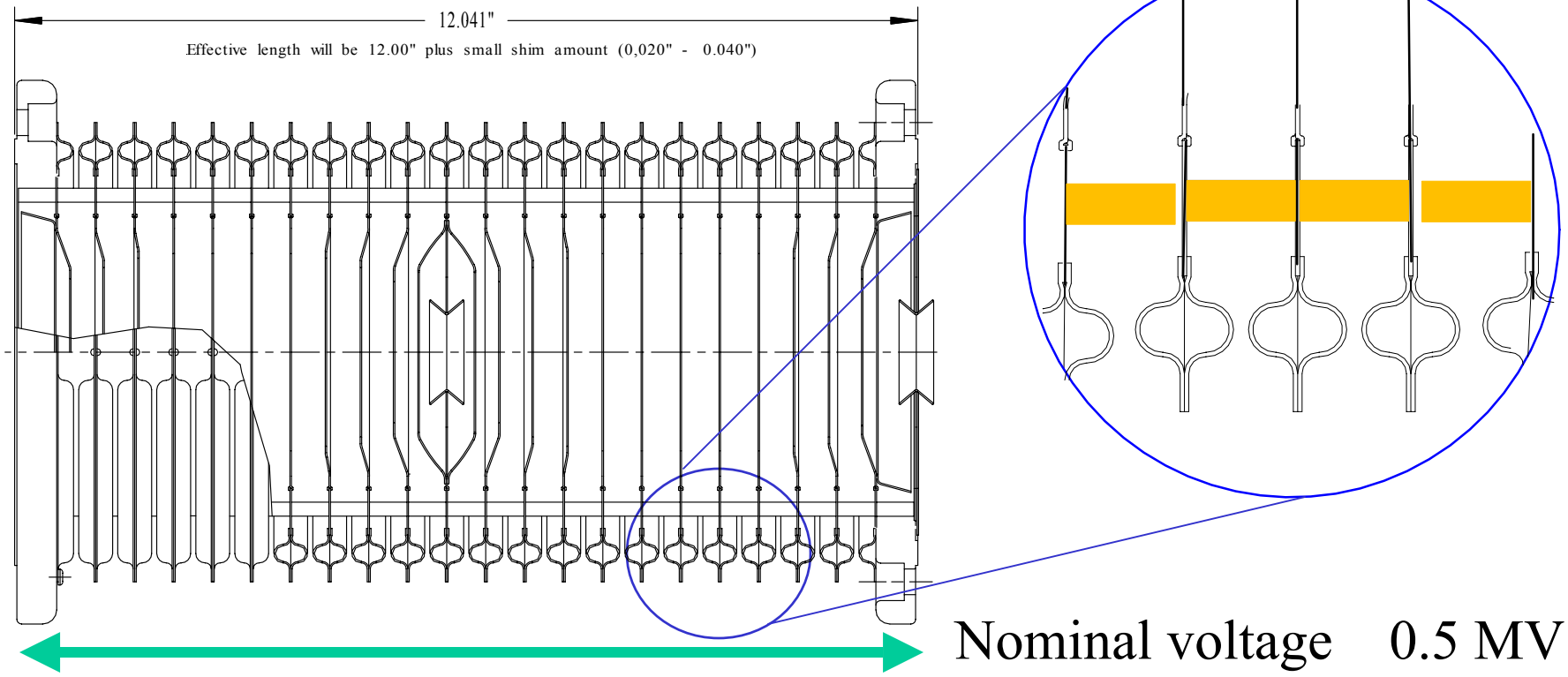
Fermilab Electron Cooling R&D Facility

The Pelletron tank is accessed through a manway.



Structure inside the tank -- separator boxes and beam lenses. No beam tubes were installed at the time of this photo.

Acceleration tube section (produced by NEC)

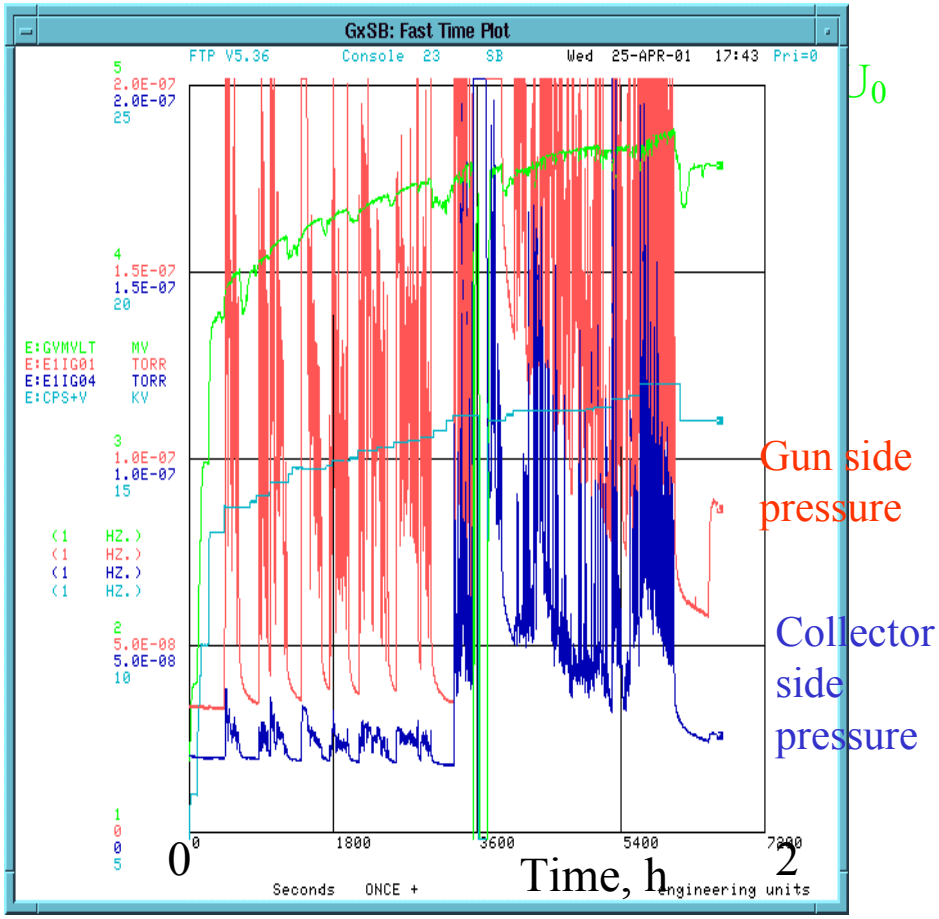


Nominal voltage 0.5 MV

Length 12”

Min. electrode ID 1”

Tube conditioning



Tube conditioning after exposing the gun tube to atmosphere.

Because of the large amount of energy (3 kJ) stored in the HV terminal and its potential for damage, HV conditioning of vacuum tubes was initially performed with the help of shorting rods, one 1-MV section at a time. Each section (out of 5) was conditioned separately to 1.2 MV. The Pelletron with tubes was then conditioned to 4.5 MV. After exposing a tube to atmosphere, conditioning can be done with all tubes connected.

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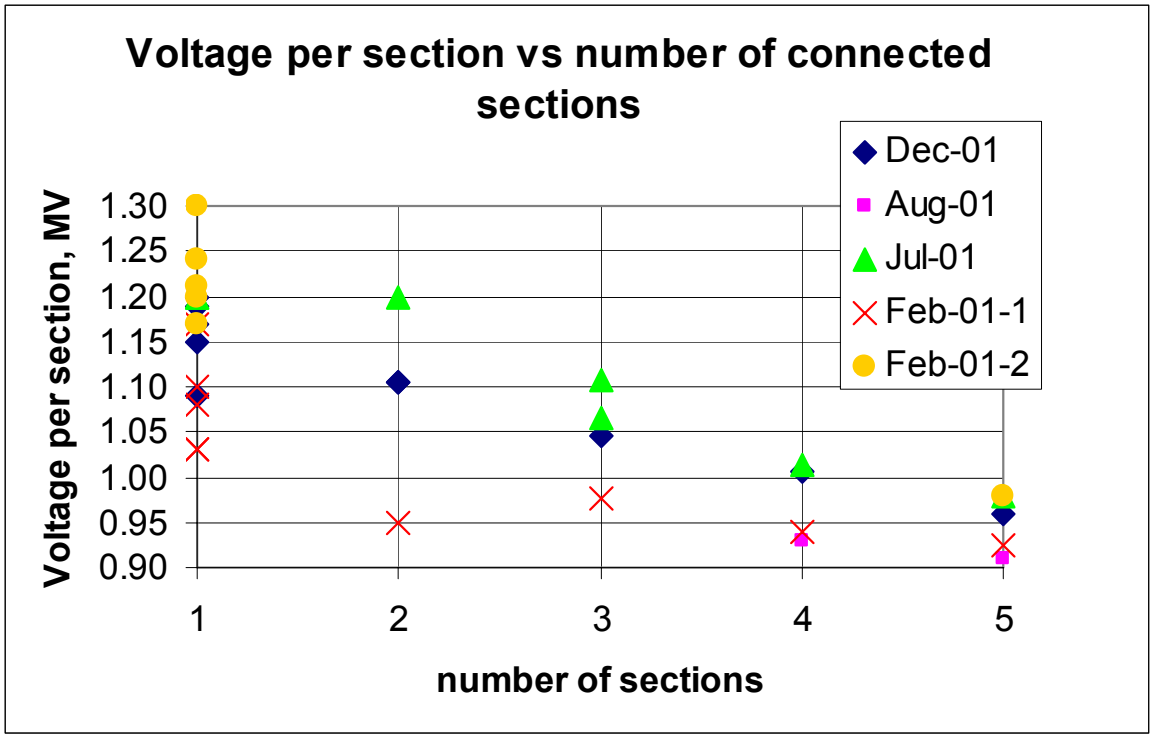
High voltage limitations



Maximum stable voltage increases non-linearly with the number of acceleration tube sections.

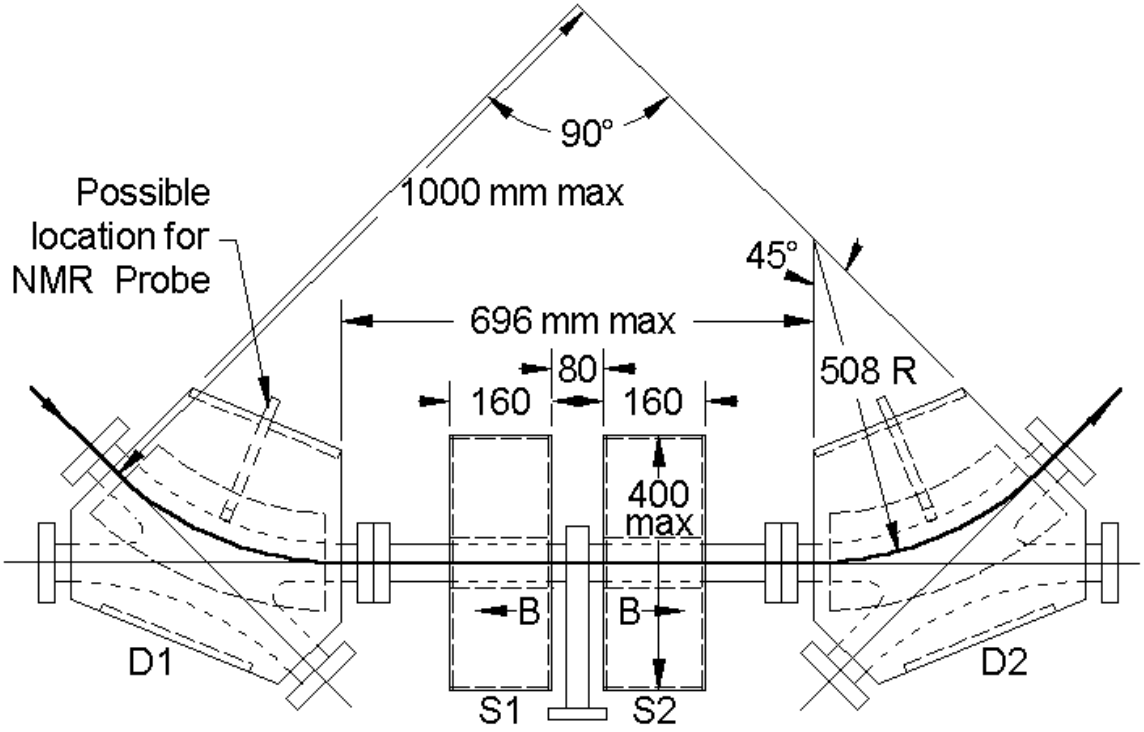
Most of full tube discharges have a detrimental effect on the tube conditioning, when the number of connected sections is more than four.

Multiple full discharges occurring during work with all sections result in a decrease of the maximum stable voltage down to ~3.8 MV, and it takes several hours to condition tubes back to the nominal voltage of 4.3 MV. That's why most of work was done at the energy of 3.5 MeV.

Plans to fix the HV problems

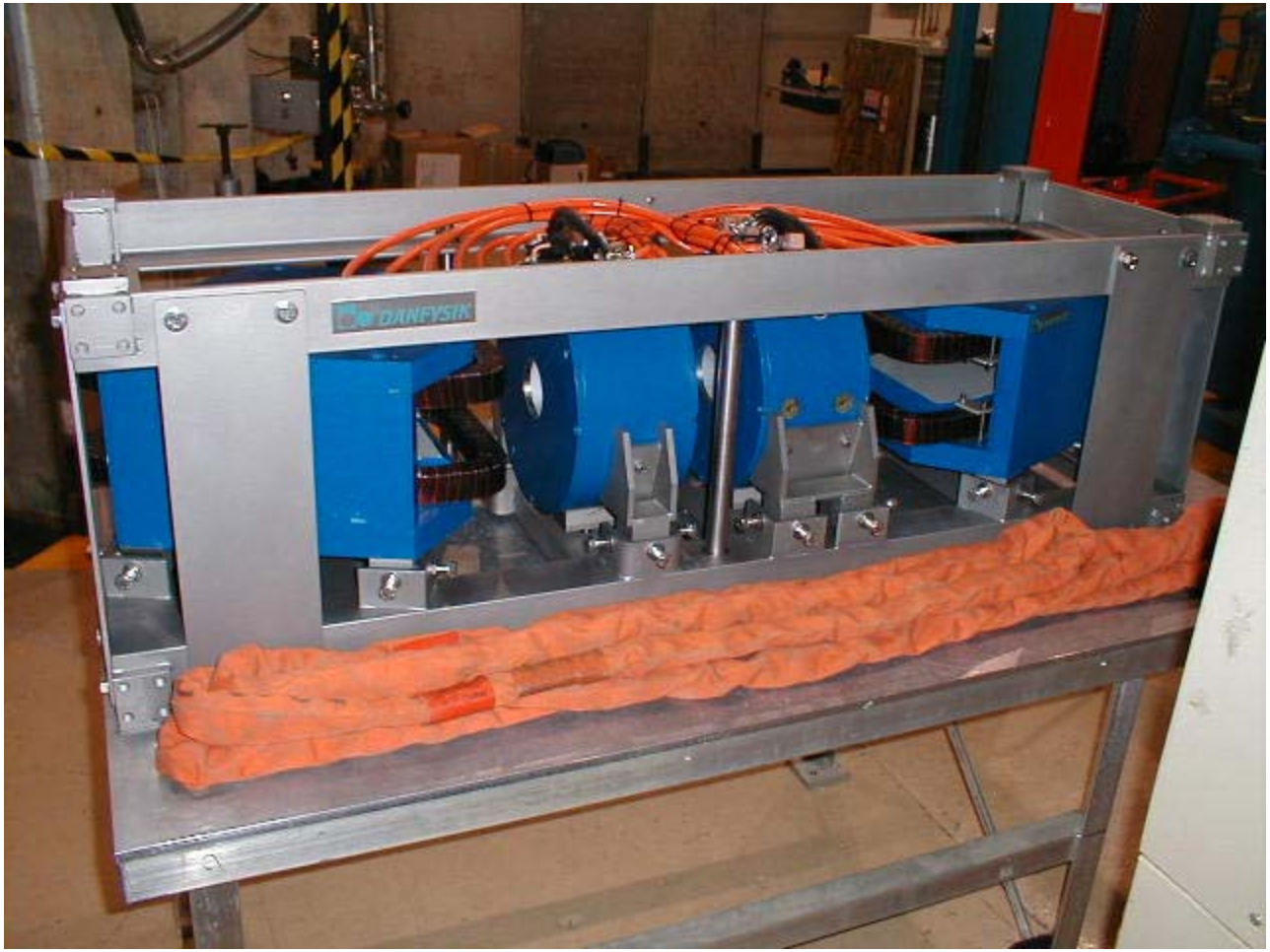
- NEC will replace the tubes with new ones on Apr. 3, 2002.
- We will run with these new tubes to determine their breakdown strength.
- If the strength is inadequate we will add one more section to the Pelletron when we move to the new building.

Beam line elements



A 90-degree dispersion-free bend is made of two NMR-regulated dipole magnets and two opposing-field solenoids. All mounted on an adjustable frame and shielded by a mu-metal shield. AL vacuum chamber will be used.

Bends received, NMR system tested



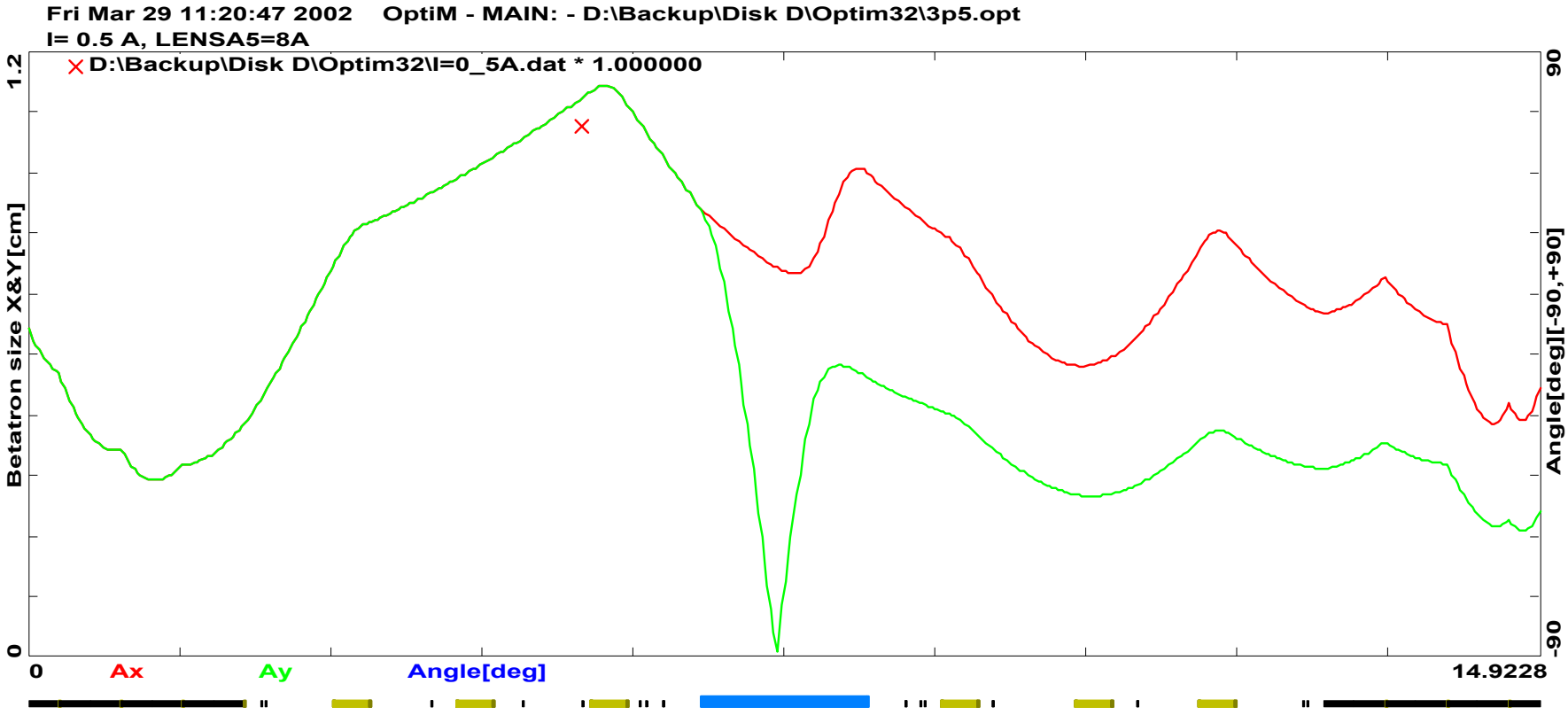
Lenses, quads, steerers

- Will be received by June 1, 2002
- PS's are all ordered and due by June 1, 2002

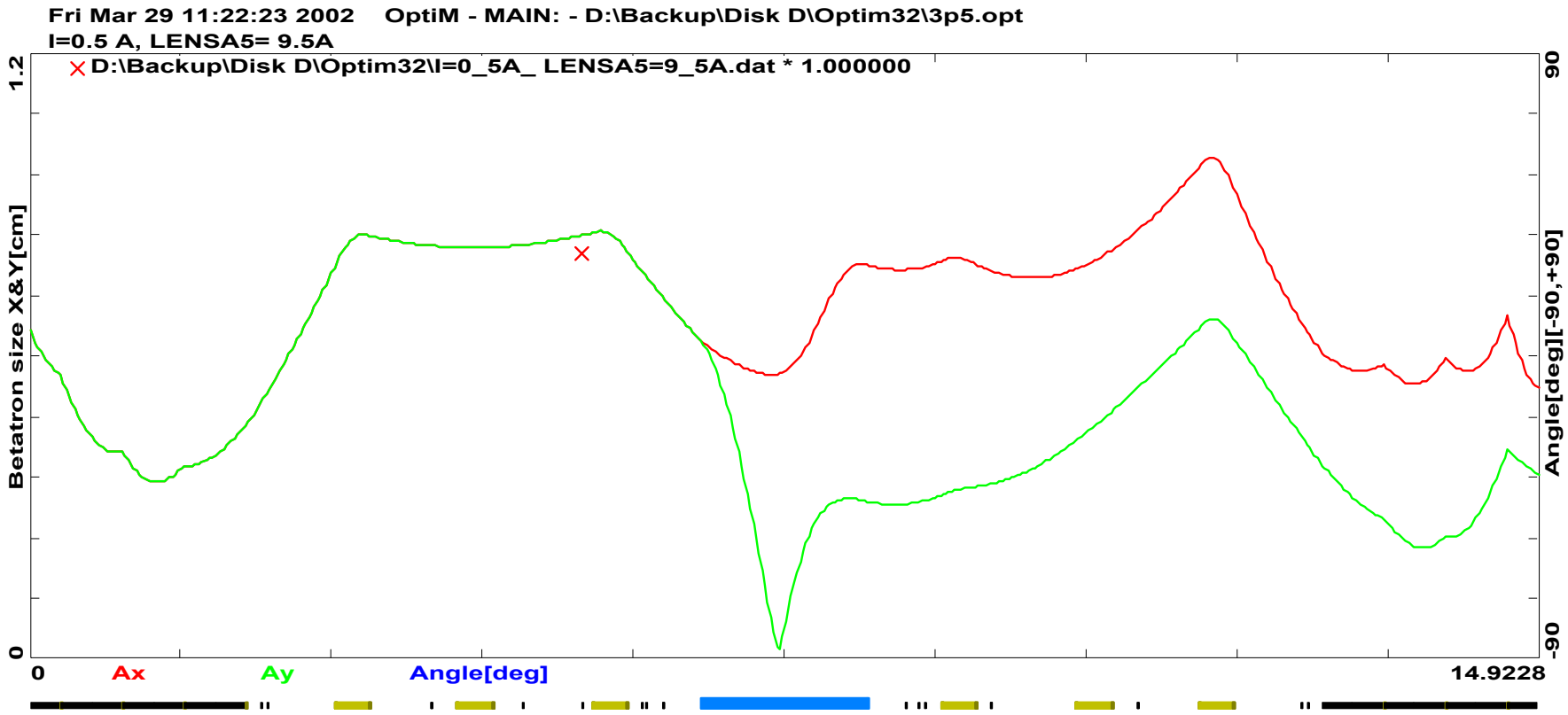
Summary on beam line diagnostics

- BPM's: require a beam modulation at 25 kHz. Need accuracy of 50 μm (1 Hz BW) to measure electron and pbar positions relative to each other. BPM plates are also used for ion clearing (1 kV). The prototype electronics was built by RFI and G. Saewert (EE). Using BPM's a good optical model has been established (just as we are about to start working with the longer beam line!)
- Flying wire: we redesigned the Tevatron FW to use a non-magnetic rotary motion feedthru. Has been tested to 4m/s and beam currents of 500 mA.
- Scrapers: used routinely to measure beam size.

Beam profile measurement with a scraper



Beam profile measurement with a scraper (different lens setting)



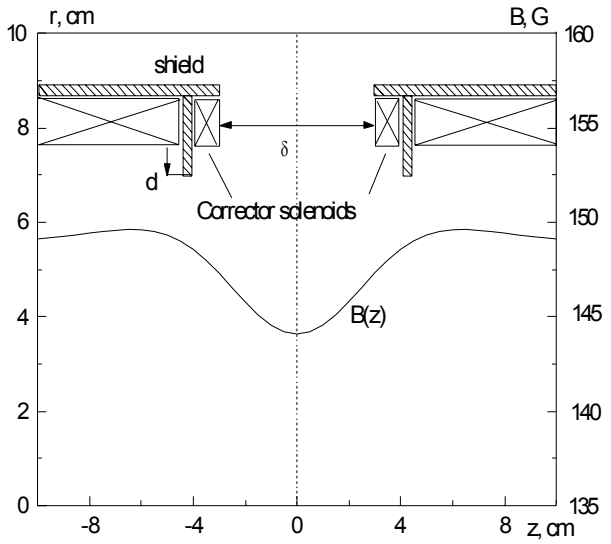
Cooling section solenoid

- consists of 10 identical solenoids in series, divided by instrumentation gaps

Total length	20 m
Magnetic field	50 - 150 G
Electron angles in the section	< 0.1 mrad
Integral of transverse magnetic field	≤ 0.3 G·cm

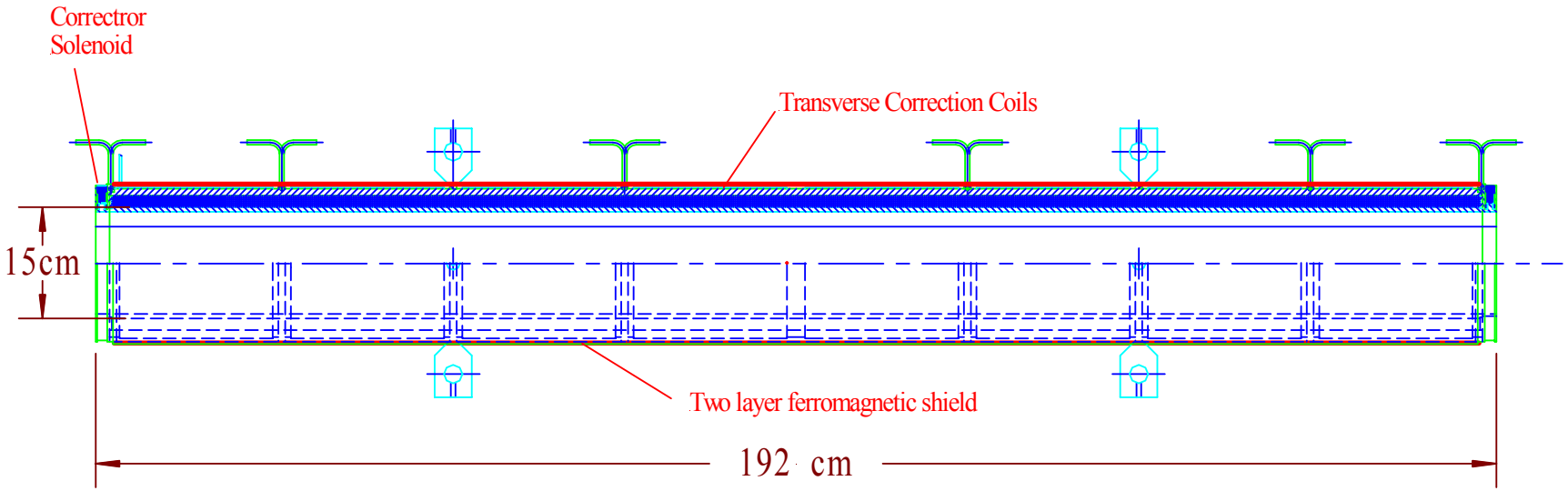
Solenoid Overview

- Ten 2-m long modules connected in series
- Each module:
  - a solenoid (188 cm long), 4 A, 80 V, 150 G
  - two corrector solenoids to correct gap effects
  - 20 transverse correctors (may be eventually connected in series with the solenoid PS)
  - 8-cm long gap for instrumentation
  - shielding with a coefficient of at least 1000 to shield stray fields of about 5 G.
- Two prototype modules were produced, installed and measured. Their properties were found satisfactory. The production of 12 more improved modules has started at Fermilab. The rate of delivery is expected to be 2 solenoids/month.

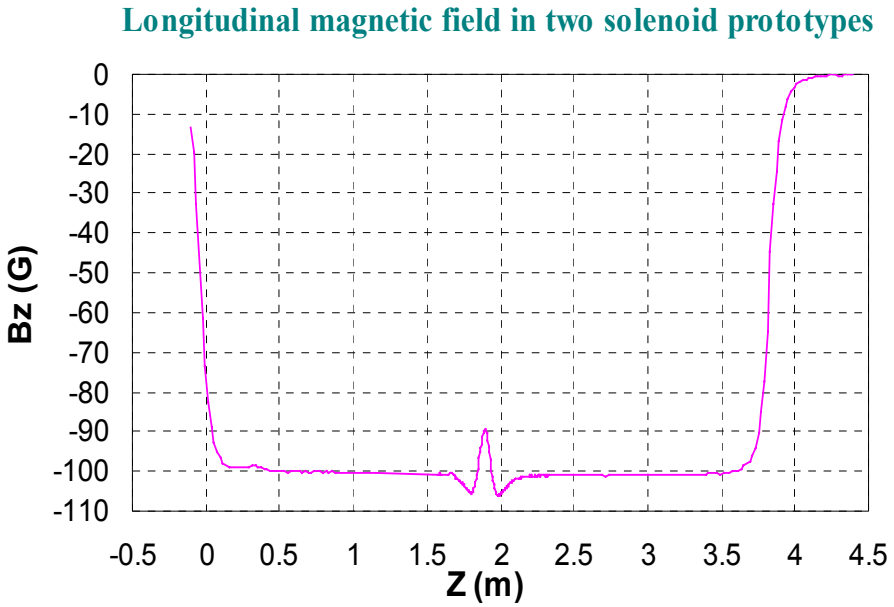


Parameters of the module solenoid

Number of layers	6
Number of turns in one layer	~980
Wire size (square AWG13)	1.88 mm
Current for B = 150 G	4 A
Total weight	250 kg
Power	240 W



Two prototype cooling section solenoid modules were measured and found to be adequate



Eleven new modules were produced and are now being installed at WideBand

MI-31 building

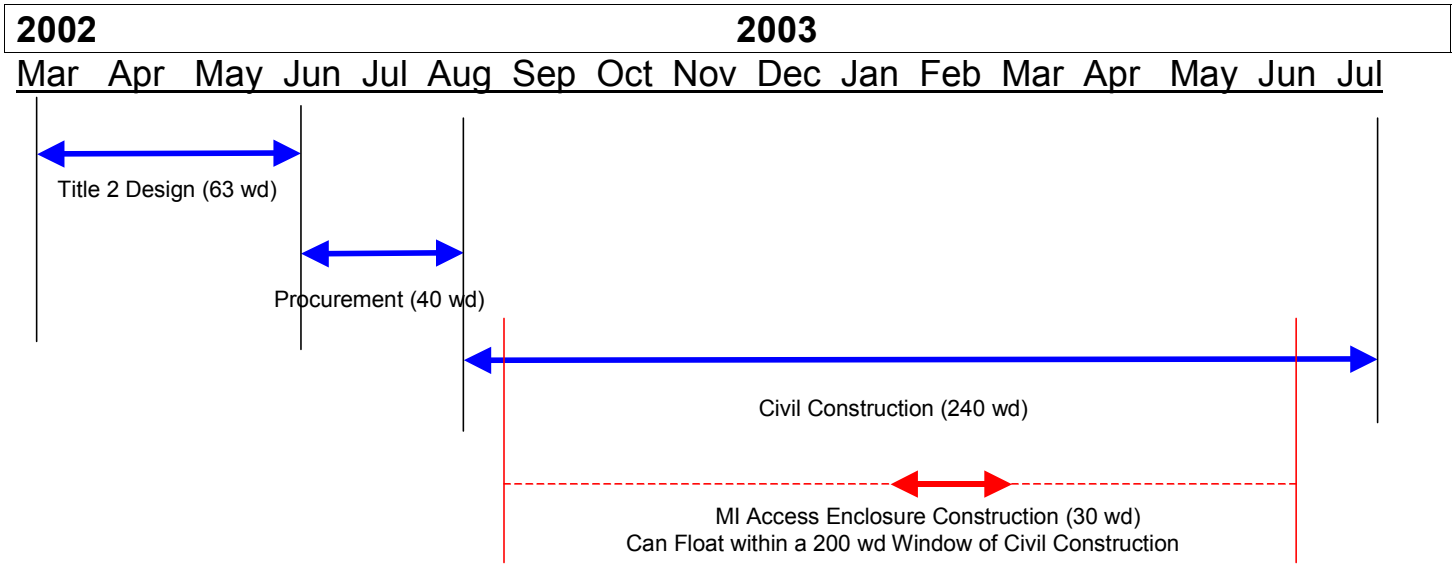
- The building CDR has been completed and reviewed
- The building design has been approved by the director's office
- The A/E firm has been hired to do the Advanced CDR as well as the Title 2 of the AIP (when approved)
- We have weekly meetings (with Ed Temple & co.) to determine the appropriate scope of the AIP
- The AIP approval review is scheduled for early May

An artist's rendering of a proposed building (MI-31)

next to the existing service building (MI-30).

S. Nagaitsev, FNAL

MI-31 project schedule



Electron Cooling Schedule (Tentative)

Project Milestone	Start Date	Finish Date	Duration
Commission U-Bend	3/01	3/02	13 months
CDR (FESS)	5/01	3/02	11 months
500 mA, 3.5 MeV, 1 hour		by 12/31/01	
Advanced CDR	3/02	5/02	2 months
FESS Title-2	5/02	6/02	1 month
Switch Over to Beamline	6/02	8/02	3 months
MI-31 bid out	6/02	8/02	3 months
Commission Beamline	8/02	6/03	10 months
500 mA, 1 hour, beam properties		by 6/03	
Build MI-31 Enclosure (NTP)	8/02	7/03	12 months
Connecting Tunnel	5/03	6/03	1.5 months
(Shutdown MI)	5/03	6/03	1.5 months
Disassemble @ Wideband	6/03	9/03	4 months
Install Pelletron @ MI-31	9/03	1/04	5 months
Shutdown MI	5/04	7/04	2 months
Install RR Components	5/04	7/04	2 months
Install Transferline	5/04	6/04	1 month
Commission E-Cool	7/04		

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